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COMPARISON OF TEACHING AND LEARNING CONCEPT NETWORKS RELATED TO ECOSYSTEM COMPOSITION IN UPPER SECONDARY SCHOOLS IN REPUBLIC OF KOREA

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Abstract. *Learning in the classroom is mainly done through verbal interaction. Since science learning is a subject in which it is difficult for students to acquire knowledge on their own, teacher guidance in class is more important. This study aimed to compare teaching and learning concept networks for the ecosystem-related content taught in upper secondary schools in the Republic of Korea. This content is divided into two classes—namely, 'Ecosystem Components' and 'Interactions between Ecosystem Components'. The key concept and connection networks for teaching and learning concepts were analysed. The study participants were 10th-grade students and three teachers who taught them. The teacher's class content was recorded, while the students' learning concepts were examined using a questionnaire. The collected data were analysed using NetMiner 4.0. The results of this study are as follows: First, the teachers and students predominantly shared the concept of the entire ecosystem; however, the detailed structures of the concept networks differed. Second, the teacher did not clearly teach the concepts of the 'Ecosystem Components' and 'Interactions between Ecosystem Components' classes and utilised the concepts repeatedly. Third, the follow-up learning content impacted the pre-learning. These findings suggest that teachers need to clearly divide concepts into each topic when teaching.*

Keywords: *ecosystem composition, upper secondary school, teaching concept network, learning concept network, connection network*

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Introduction

Learning in the classroom is accomplished through interaction between teachers and students. Most of this interaction is done through language. Learning in the classrooms is accomplished through teachers conveying knowledge, or concepts to students through verbal interaction. An important goal of education is helping students understand scientific concepts (Gauld, 2001; MOE, 2015; Smith & Siegel, 2004). Specifically, as independently acquiring knowledge in science is challenging for students, they learn most scientific concepts through teacher guidance in class (Mallow, 1986).

Learning outcomes differ significantly depending on how teachers plan and implement classes in schools (Pianta & Hamre, 2009; Powell & Anderson, 2002; Schenke et al., 2017; Waller, 2006). However, teachers—despite aiming to facilitate students' concept formation through explanation—generally do not consider how students understand and construct cognitive structures for these concepts (Widodo & Duit, 2002; Widodo et al., 2002). Therefore, teachers should understand the conceptual structure that they use to explain concepts and the one that students employ to acquire concepts in class (Chun et al., 2024; Lim et al., 2024).

Semantic network analysis (SNA) is primarily utilised to determine the structure of concepts in students' cognitive structures (Choi et al., 2017). It has the advantage of concretising abstract semantic structures by analysing the connection patterns between concepts and visualising hidden structures (Doerfel & Barnett, 1999).

Previous studies employing SNA methods have analysed connections between concepts (Chung et al., 2018; Kim & Kwon, 2016; Kim et al., 2019) and students' concept networks (Lim et al., 2020). Additionally, studies have analysed teachers' teaching concepts and students' learning concepts. For

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example, studies have investigated these concepts vis-à-vis Mendelian principles of inheritance (Kim et al, 2023; Lim et al., 2024) and photosynthesis (Chun et al., 2024; Yoo et al., 2024) units in lower secondary school; these studies must be expanded by targeting upper secondary school students.

In the Republic of Korea's curriculum, ecosystem-related content is taught in elementary and upper secondary schools. In upper secondary schools, students are taught to understand both the ecosystem's components and the interrelationship between organisms and the environment (MOE, 2015). To this end, teachers divide the science class into ecosystem components and interactions between ecosystem components. Ecosystem-related content's importance is further highlighted by its suitability for teaching systems thinking (Evagorou et al, 2009; Lee et al., 2019), which is emphasised as a prerequisite for functioning effectively and responsibly in a complex world (Arndt, 2006; Eilam, 2012; Jacobson & Wilensky, 2006).

Theoretical Background

Taught Curriculum and Learned Curriculum

The interaction between teachers and students facilitates the teaching–learning process in class. Taught curriculum refers to the process whereby teachers practice in class by integrating school education's needs, expectations, and intentions with students' situations and needs (Karabacak & Kürüm-Yapıcıoğlu, 2020). Meanwhile, learned curriculum refers to students' actual learning in class, with the learned content residing within their cognitive structures (Amineh & Asl, 2015; Glatthorn, 2000).

Students remember their learning and, when necessary, recall and recognise it (May et al., 2013). Assessing whether students remember and retrieve their learning helps ascertain whether learners have effectively learned the taught concepts (Jensen, 2005). Therefore, analysing learners' memories is one means to comprehend the cognitive structure that learners have learned and, arguably, to provide clues for deriving and understanding learning outcomes (Schwartz et al., 2011).

Examining retrieved memory helps ascertain the classroom learning that the learner remembers and the organisation and structuring of their knowledge into cognitive structures. Notably, SNA is employed to determine these learners' cognitive structures. Specifically, it can demonstrate these structures' organisation by identifying the connections between concepts within them (Kenett & Faust, 2019; Koponen & Nousiainen, 2014).

Learning occurs when students construct their own concepts based on the teacher's classes (Earl, 2013). Therefore, taught and learned curricula are interconnected, with any discrepancy between them precipitating problems in achieving class goals (Blank et al., 2001; McGehee & Griffith, 2001; Porter & Smithson, 2002). Therefore, analysing the kind of conceptual structure used by the teacher and that employed by the student is necessary, as is examining the alignment between the taught and learned curricula.

Ecosystem-related Contents in the Republic of Korea's Curriculum

This study's research subject was the ecosystem-related content in the Republic of Korea's curriculum. This content specifically referred to the class called 'Ecosystem Components'—taught in the 5th and 9th grades. The 5th-grade science curriculum aims to facilitate an understanding of the ecosystem, including living things and abiotic environmental factors influencing their lives. Accordingly, the relationship between living things and the environment is taught through examples of environmental factors (e.g., light, water, and temperature) that impact living things' lives and how they adapt to the environment.

In the 9th-grade integrated science curriculum, the 'Ecosystem and Environment Class' is taught. This class aims to facilitate an understanding of the ecosystem's components (including humans), the mutual relationship between organisms and the environment, and the necessity of preserving the ecosystem. Subsequently, cases of ecosystem balance and environmental changes impacting the ecosystem are investigated (MOE, 2015). This study selected the ecosystem's components and interactions between organisms and the environment as its research subjects.

Research Aim and Research Questions

Teaching and learning are interconnected, and the alignment between them is a very important measure for achieving the learning objectives. Therefore, the purpose of this study was to analyse the alignment between the taught curriculum and the learned curriculum from a conceptual perspective, and to suggest implications

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for teaching-learning strategies. To this end, this study attempted to compare the concepts that teachers use to teach, the concepts that students acquire through learning, and the concepts that they remember over time by structuring them into a concept network.

Therefore, this study aimed to analyse the concept networks taught by teachers and those learned by students regarding ecosystem-related content taught in upper secondary schools. This content is divided into ecosystem components and interactions between ecosystem components. Specifically, the following networks were analysed: the teacher's key teaching concept, the student's key learning concept, and the connection concept networks. That is, this study analysed the concept network that teachers teach concerning the ecosystem-related content and the resultant concept network that students learn. The research problem for this study is as follows.

What are the differences between teachers' teaching concept networks and students' learning concept networks in relation to the contents of the ecosystem composition of upper secondary school?

Research Methodology

Design

This study was designed to compare teachers' teaching concepts and students' learning concepts related to ecosystem content using network analysis in upper secondary schools in the Republic of Korea. Network analysis is an objective and scientific research method that complements the limitations of qualitative research methods that analyse the teaching and learning process in existing schools (Lee & Jeong, 2019).

The teaching concept network visualized the concepts used by teachers by recording the teachers' classes related to ecosystem contents. The student learning concept network visualized the concepts answered by students as a network using a learning memory questionnaire.

In integrated science in the Republic of Korea, ecosystem-related content is presented in the 'Ecosystem and Environment' unit, which is divided into two topics: 'Ecosystem Components' and 'Interactions between Ecosystem Components.' Each topic was conducted for 50 minutes, totalling 100 minutes. The class is conducted as a teacher-centred class, where the teacher primarily explains the material to the students. The actual class was conducted from October to December 2024 in accordance with the curriculum progress plan of the school to which the participants belonged. The content of the class was recorded and videotaped with the teacher's consent. The students' learning concepts through the class were collected through a learning memory questionnaire immediately after the class and four weeks after the class.

Participants

To analyse the network of teachers' teaching concepts and students' learning concepts regarding the ecosystem taught in upper secondary schools in the Republic of Korea, teachers and students from three upper secondary schools in a metropolitan city with a population of over 2.8 million were selected as participants. The academic achievement levels of students in the selected upper secondary schools correspond to those of students in the upper secondary schools in the Republic of Korea. This study's purpose, significance, and method were explained to the teachers and students, all of whom agreed with the same. The students were asked to respond to the questionnaire voluntarily.

All teachers were female, with their teaching experience ranging from 4 to 10 years. The study sample included 298 tenth-grade students. This is because all students taught by the subject teachers were sampled in order to analyse reliable learning concept networks. A large number of texts increases the reliability of the analysis results. The final analysis only included students who completed the questionnaires immediately after class and the follow-up test conducted four weeks later. Students who listed only concepts were excluded from the analysis. Consequently, the final number of students analysed was as follows: 85 students (43 male, 42 female) for the 'Ecosystem Components' class and 71 students (30 male, 41 female) for the 'Interactions between Ecosystem Components' class. At this time, when the sample size for semantic network analysis exceeds 15, it can be considered a sufficient sample based on evidence showing a high correlation of more than 90% with the population (Lim & Lee, 2013).

According to Article 2 of the Elementary and Secondary Education Act and Article 2 of the Higher Education Act of the Republic of Korea, research related to practical work within the scope of the school curriculum is subject to research ethics exemption (KoNIBP, 2018). Before conducting this study, measures such as obtaining consent

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were taken after notifying the school, students, and parents that the personal information of participants would not be collected or recorded.

Ecosystem Classes

Classes were conducted based on the curriculum progress plan of the school to which the participants belonged. The class covered ecosystem components and the interactions between these components; the classes were conducted for 50 minutes each, totalling 100 minutes.

The content of the 'Ecosystem Components' class aims to facilitate the understanding of the meaning and examples of biotic and abiotic factors that constitute the ecosystem. The teacher divided biotic factors into producer, consumer, and decomposer, and levels, such as individual, population, and community, explaining the meaning of each and illustrating them with examples of living things commonly seen around us. For abiotic factors, the teacher first explained the meaning and then provided explanatory examples, such as soil, air, and water.

The content of the 'Interactions between Ecosystem Components' class aims to facilitate an understanding of how biotic and abiotic factors constituting an ecosystem impact each other. The teacher utilised varied examples to explain the effects of biotic factors on abiotic factors and those of abiotic factors on biotic factors, with the former illustrated using examples of plants and animals.

Questionnaire

A learning memory questionnaire was used to collect data and describe students' learning concepts related to ecosystem components and interactions between these components. The learning memory questionnaire used a questionnaire that was verified in previous studies (Chun et al., 2024; Lim et al., 2020). The learning memory questionnaire was modified and supplemented to fit the subject of this study, 'Ecosystem Components' and 'Interactions between Ecosystem Components' classes. For this, two seminars were held with two biology education experts, one doctoral student, and two master's students. The questionnaire—created using Google Forms—comprised learning topics, learning objectives, writing methods, and writing examples.

Data Collection and Analysis

First, the class conducted by the teacher was recorded and videotaped to analyse the concept network taught by the teacher. The collected data were transcribed into a text file (.txt). Subsequently, the students were required to complete two questionnaires to determine their learning concepts. The questionnaires were administered via a Google form on a tablet PC under the teacher's supervision and took approximately 10 minutes to complete. Thereafter, the responses to the questionnaires were also transcribed as a text file (.txt).

The collected data regarding the concepts taught by teachers and those learned by students were utilised to extract concepts using Net Miner 4.0. A dictionary of exclusion words was created to remove non-scientific concepts from the extracted concepts; further, a thesaurus was created to integrate words with similar meanings (Kim et al., 2023; Yun & Park, 2018). Based on this process, 56 concepts were selected.

To ensure that only the concepts essential for learning 'Ecosystem Components' and 'Interactions between Ecosystem Components' were included among the selected concepts, concept validity was reviewed by two biology education experts and four current life science teachers. These life science teachers had over 10 years of teaching experience, while two had master's degrees and two had doctoral degrees. Consequently, 45 concepts were finally selected.

For the concepts finally selected, the key concept and connection concept networks were analysed as 1-mode and 2-mode, respectively. The key concept and connection concept networks involved concepts with a frequency rate of 30% or higher, targeting concepts that both teachers and students primarily presented. Figure 1 depicts an example of a network visualising all the concepts taught by teachers in class. This study elucidated the key concept and connection concept networks.

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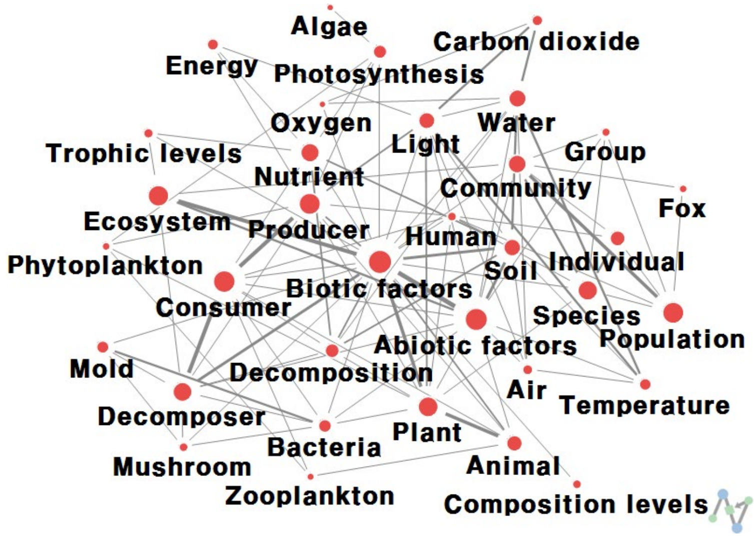
Figure 1

Example of a Network of All Concepts Taught by Teachers in the 'Ecosystem Components' Class



Research Results

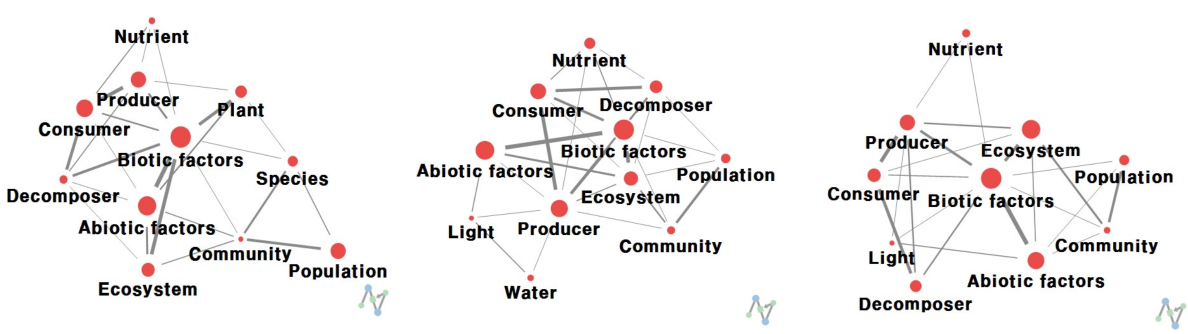
Network of Key Concepts

Ecosystem Components

Figure 2 depicts the networks of key concepts for the ecosystem components class as follows: (a) teaching concepts, (b) learning concepts after class, and (c) learning concepts at follow-up. The total number of teaching concepts is 11 (Figure 2a). The teaching concept network centres around 'Biotic factors', 'Abiotic factors', and 'Community'. 'Biotic factors' are connected to 'Producer', 'Plant', 'Community', and so on. 'Abiotic factors' are connected to Ecosystem', 'Plant', 'Consumer', and so on. Finally, 'Community' is connected to 'Species', 'Population', 'Ecosystem', and so on.

Figure 2

Networks of Key Concepts for Ecosystem Components



a) Teaching concepts   b) Learning concepts after class   c) Learning concepts at follow-up

The total number of learning concepts after class is 11 (Figure 2b). The learning concept network after class centres around 'Biotic factors', 'Producer', and 'Ecosystem'. 'Biotic factor' is connected to 'Consumer', 'Nutrient', and

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'Ecosystem'. 'Producer' is connected to 'Biotic factors', 'Light', and 'Community'. Finally, 'Ecosystem' is connected to 'Biotic factors', 'Abiotic factors', and 'Water'.

Ten learning concepts are observed at follow-up (Figure 2c). The learning concept network at follow-up centres around 'Biotic factors', 'Community', and 'Producer'. 'Biotic factors' is connected to 'Producer', 'Nutrient', and 'Consumer'. 'Community' is connected to 'Population', 'Ecosystem', and 'Species'. Finally, 'Producer' is connected to 'Biotic factors', 'Ecosystem', and 'Nutrient'.

Most key concepts presented in teaching concepts, learning concepts after class, and learning concepts at follow-up were the same, but some differed. The concepts of 'Light' and 'Water'—examples of abiotic factors—appeared in the student's learning concept network immediately after class, but not in the teacher's teaching concept network or the student's learning concept network at follow-up. The students' concept networks immediately after and four weeks after class exhibited a higher relative frequency of 'Ecosystem' and were connected to more concepts than the teacher's teaching concept network. This was believed to be the result of students integrating the concepts learned in class based on their holistic understanding of the ecosystem.

Interactions between Ecosystem Components

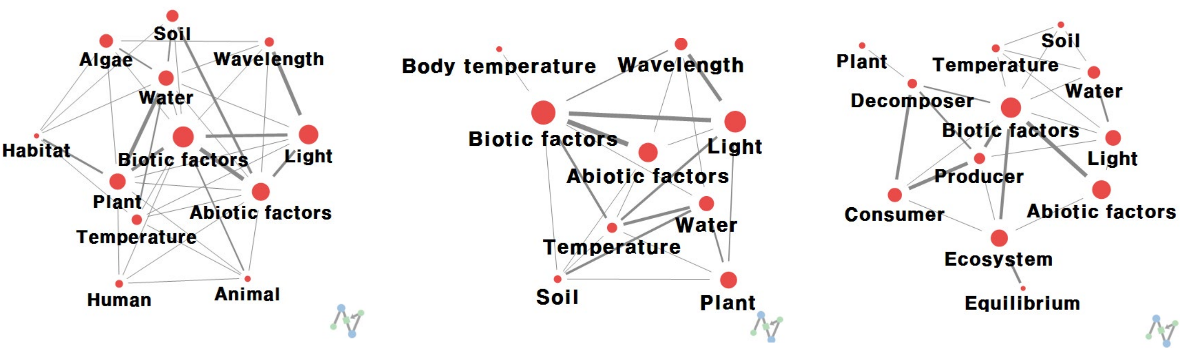
The networks for teaching concepts, learning concepts after class, and learning concepts at follow-up regarding 'Interactions between Ecosystem Components' are analysed (Figure 3). The total number of teaching concepts in the key concept network is 12 (Figure 3a). The teaching concept network centres around 'Biotic factors', 'Abiotic factors', and 'Water'. 'Biotic factors' are connected to 'Plant', 'Algae', and 'Abiotic factors'. Further, 'Water' is connected to 'Plant', 'Habitat', and 'Temperature'. Finally, 'Abiotic factors' are connected to 'Light', 'Soil', and 'Plant'.

The total number of learning concepts after class in the key concept network is 11 (Figure 3b). The key concept network for learning concepts after class centres around 'Biotic factors', 'Temperature', and 'Water'. 'Biotic factors' is connected to 'Poikilotherm', 'Body temperature', and 'Wavelength'. 'Temperature' is connected to 'Animal', 'Plant', and 'Biotic factors'. Finally, 'Water' is connected to 'Soil', 'Plant', and 'Animal'.

Twelve learning concepts are observed at follow-up in the key concept network (Figure 3c). The key concept network for learning concepts at follow-up centres around 'Biotic factors', 'Light', and 'Producer'. 'Biotic factors' is connected to 'Producer', 'Consumer', and 'Temperature'. 'Light' is connected to 'Producer', 'Biotic factors', and 'Temperature'. Finally, 'Producer' is connected to 'Ecosystem', 'Consumer', and 'Light'.

In the key concept network for teaching and learning concepts after class, 'Plant' was connected to various concepts, such as 'Biotic factors' and 'Abiotic factors', thereby forming a complex mesh. However, in the network for learning concepts at follow-up, 'Plant' was connected only to 'Oxygen' and 'Decomposer', thus demonstrating a linear form. This indicated that students effectively remember the relationship between 'Plant' and other concepts taught by the teacher immediately after class; however, most relationships between 'Plant' and other concepts were forgotten after four weeks.

Figure 3
Networks of Key Concepts for the 'Interactions between Ecosystem Components'



a) Teaching concepts b) Learning concepts after class c) Learning concepts at follow-up

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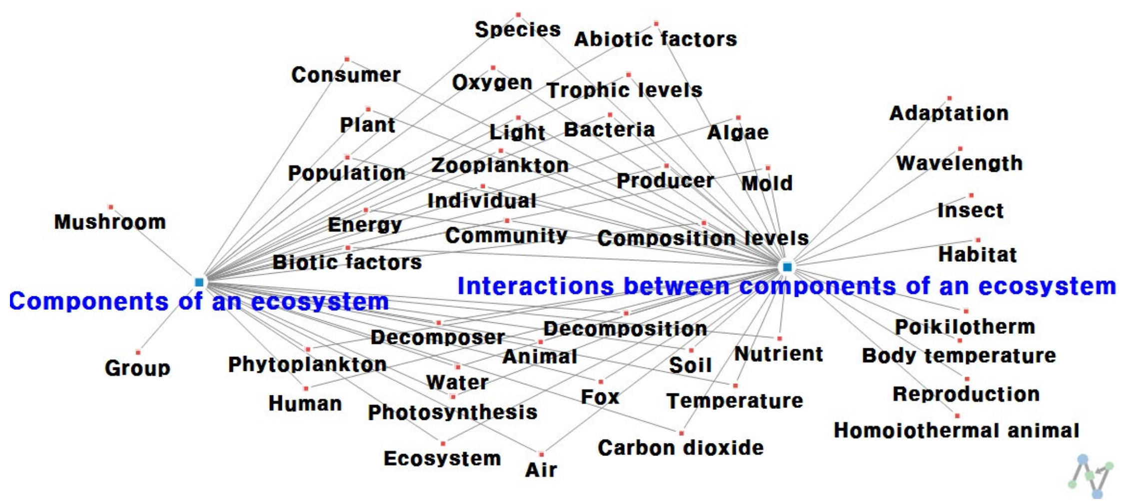
Connection Network

Connection Network between Classes

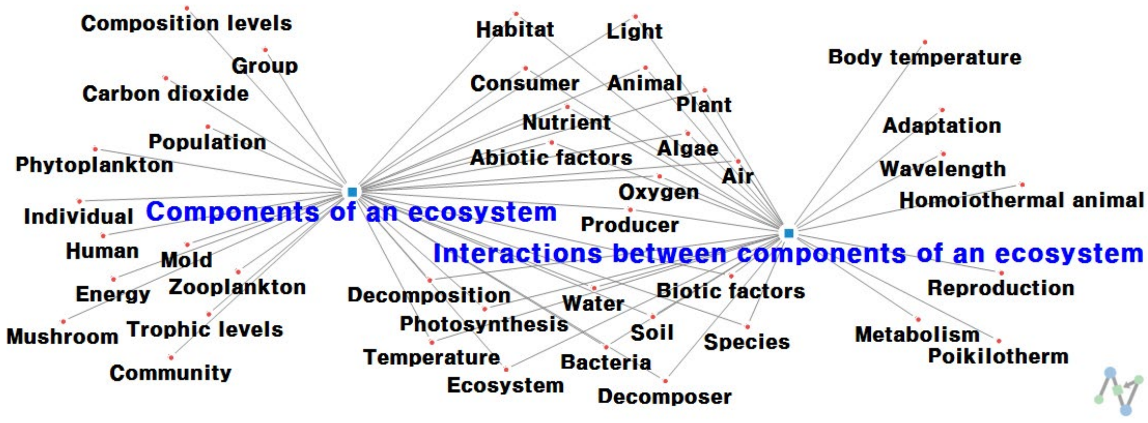
The connection networks of the concepts presented in the 'Ecosystem Components' and 'Interactions between Ecosystem Components' classes are analysed (Figure 4). In the connection network of teaching concepts (Figure 4a), the number of concepts utilised in both classes is 32, including 'Biotic factors', 'Abiotic factors', 'Nutrient', 'Air', and 'Energy'. The number of concepts employed only in the 'Ecosystem Components' class is two, namely, 'Group' and 'Mushroom'. Finally, the number of concepts utilised only in the 'Interactions between Ecosystem Components' class is six, including 'Body temperature' and 'Adaptation'.

Analysing the connection network for learning concepts after class (Figure 4b) reveals 25 commonly appearing concepts, including 'Producer', 'Consumer', 'Decomposer', 'Population', and 'Ecosystem'. Eight concepts appear only in the 'Ecosystem Components' class, including 'Zooplankton', 'Phytoplankton', 'Composition levels', 'Trophic levels', and 'Mold', while six concepts appear only in the 'Interactions between Ecosystem Components' class, including 'Reproduction', 'Metabolism', 'Body temperature', and 'Poikilotherm'.

Figure 4
Connection Networks Between Classes



a) Teaching concepts



b) Learning concepts after class

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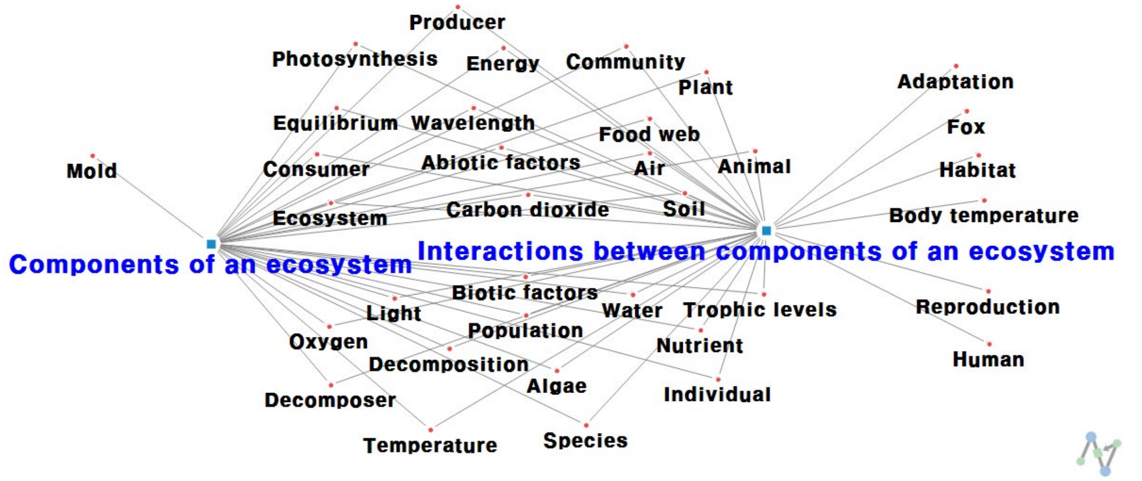

c) Learning concepts at follow-up

In the connection network for learning concepts at follow-up (Figure 4c), 28 commonly appearing concepts are observed, including 'Food web', 'Individual', 'Temperature', 'Equilibrium', and 'Carbon dioxide'. Seven concepts appear only in the 'Interactions between Ecosystem Components' class, including 'Human', 'Body temperature', 'Poikilotherm', 'Fox', and 'Adaptation', while one concept appears only in the 'Ecosystem Components' class, namely, 'Mold'.

Connection Network between Teaching Concepts, Learning Concepts after Class, and Learning Concepts at Follow-up for Each Class

In the 'Ecosystem Components' class, the connection networks for teaching concepts, learning concepts after class, and learning concepts at follow-up are analysed (Figure 5a). The commonly presented concepts are 26 in total, including 'Biotic factors', 'Abiotic factors', 'Nutrient', 'Plant', and 'Decomposer'. The number of concepts that appeared only in teaching and learning concepts after class is seven, including 'Mushroom', 'Composition levels', and 'Bacteria'. By contrast, the concept presented only in the teaching concepts is 'Fox', while that presented only in the learning concepts after class is 'Habitat'. Finally, the concepts presented only in the learning concepts at follow-up are 'Equilibrium', 'Food web', and 'Wavelength'.

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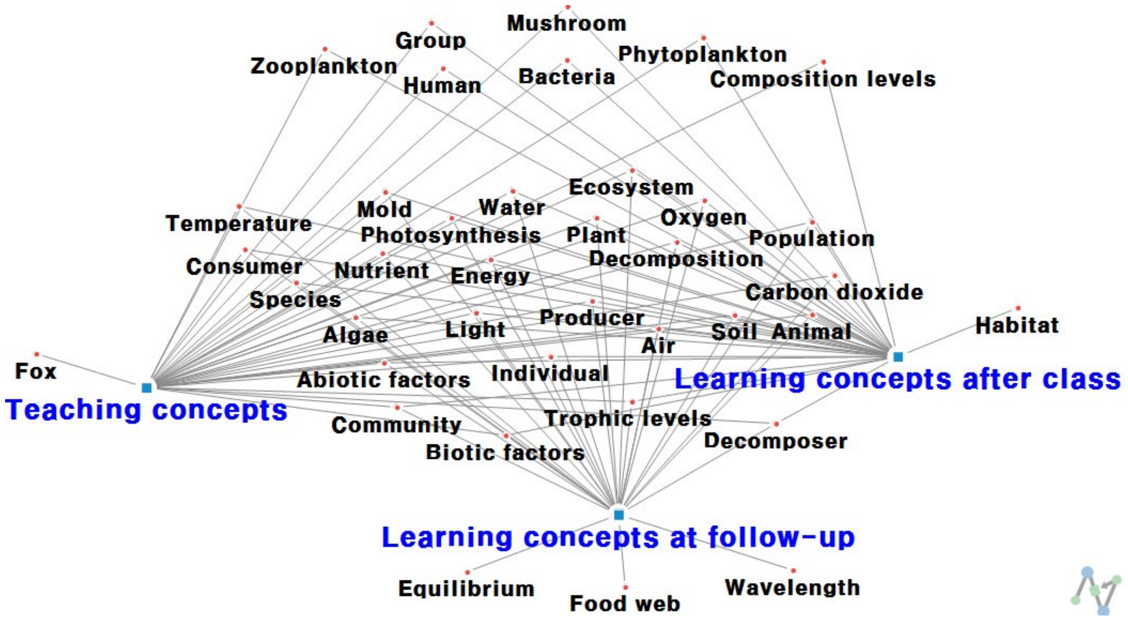
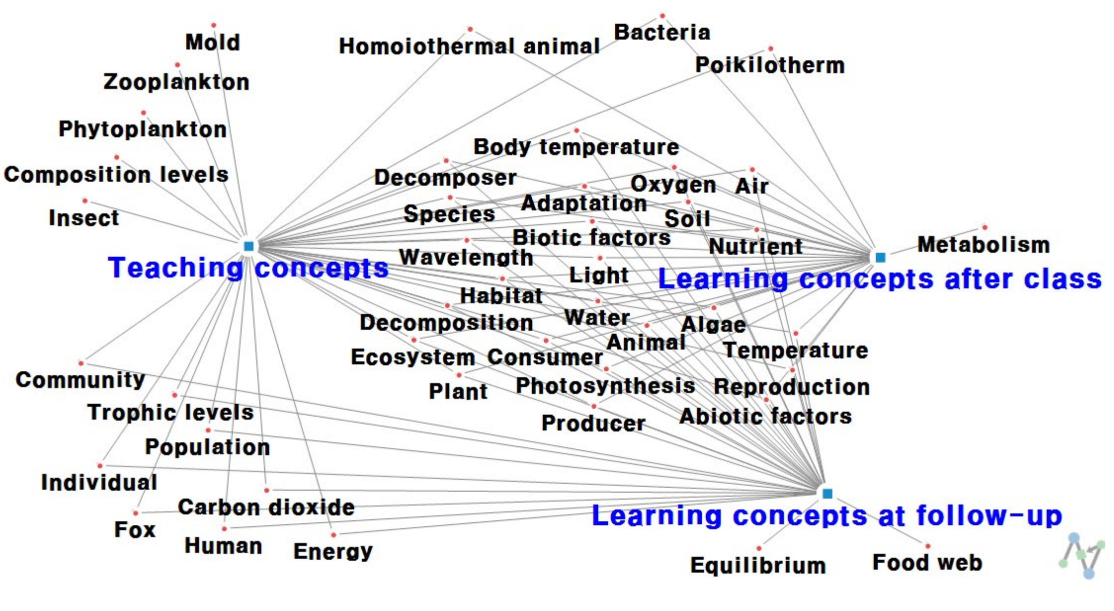
Figure 5

Connection Networks Between Teaching Concepts, Learning Concepts After Class, and Learning Concepts at Follow-up for Each Class



a) 'Ecosystem Components' class



b) 'Interactions between Ecosystem Components' class

In the 'Interactions between Ecosystem Components' class (Figure 5b), the concepts commonly presented in teaching concepts, learning concepts after class, and learning concepts at follow-up include 'Biotic factors', 'Abiotic factors', 'Wavelength', 'Body temperature', and 'Algae', among others, totalling 24 concepts. The concepts commonly presented in teaching and learning concepts after class are 'Bacteria', 'Homoiothermal animal', and

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'Poikilotherm' for three concepts. Further, the concepts commonly presented in teaching and learning concepts at follow-up are 'Population', 'Carbon dioxide', and so on, for eight concepts. By contrast, the concepts presented only in the teaching concept are 'Mold', 'Zooplankton', 'Phytoplankton', 'Composition levels', and 'Insects', while the concept presented only in the learning concepts after class is 'Metabolism'. Finally, the concepts presented only in the learning concepts at follow-up are 'Equilibrium' and 'Food web'.

Noteworthily, teaching concepts, learning concepts after class, and learning concepts at follow-up were generally similar. However, in the learning concepts at follow-up, the teacher presented a concept called 'Food web', which was not taught in the 'Ecosystem Components' class but appears in a follow-up class called 'Ecosystem Equilibrium' after learning all the contents. This concept's incorporation demonstrated that students connect concepts learned in class with concepts learned later.

Discussion

This study examined the networks for teaching concepts, learning concepts after class, and learning concepts at follow-up vis-à-vis ecosystem-related content in upper secondary schools in the Republic of Korea. The key concepts taught by the teachers and those learned by students were similar (Figure 5), whereas the structures of the teaching and learning concept networks differed—consistent with previous findings (Chun et al., 2024; Lim et al., 2020).

In the 'Ecosystem Components' class, the teacher focused on teaching biotic factors (Figure 2a). Immediately after the class, students formed a network that included both 'Biotic factors' and 'Abiotic factors' (Figure 2b); however, four weeks later, they formed a network centred on 'Biotic factors' (Figure 2c). Additionally, in the 'Interactions between Ecosystem Components' class, the teacher explained how abiotic factors impact animals and plants. Immediately after the class, students formed a network centred on the 'effects of abiotic factors on plants'; nevertheless, four weeks later, they could not form a network centred on biotic factors and the relationship between the types of abiotic factors and plants.

In classes incorporating inquiry activities, teachers provided concept-centred explanations, but students formed networks including concepts related to the inquiry (Lim, Kim & Kim, 2024). In classes not incorporating inquiry activities, structures were formed related to concepts such as 'biological factors'. Furthermore, students could not clearly distinguish between subtopics and form concept networks (Chun et al., 2024)—consistent with Case et al.'s (1996) finding that students' development of concept structures is impeded by unclear subtopic distinction.

The teacher presented a large number of concepts while conducting the class. Among the concepts utilised to explain examples of interactions between ecosystem components, 'Zooplankton', 'Phytoplankton', 'Insect', and 'Mold' were not retained by the students immediately after and four weeks after the class (Figure 5b). This finding is attributable to the teacher's belief that they must teach a large number of concepts to the students (Jeong et al., 2010).

The teacher repeatedly used the concepts in class. Notably, 32 concepts appear simultaneously in the classes of the 'Ecosystem Components' and 'Interactions between Ecosystem Components' classes (Figure 4). This is primarily because biology is the science of living systems, is inherently hierarchical, and comprises varied subsystems (Ginsburg et al., 1998; Momsen et al., 2022). Seemingly, as the teacher's explanation did not differentiate between the two classes' concepts and repeatedly overlapped, the students could not clearly distinguish between them.

After four weeks, the students' follow-up concepts incorporated concepts that were not explained in class. The concepts that emerged four weeks after class were 'Equilibrium' and 'Food web'—attributable to the content focusing on ecosystem equilibrium, which was taught after the lesson on the 'Interactions between Ecosystem Components' class. This finding indicates that students' subsequent learning influences their prior learning, resulting in them reconstructing their learning content (Noddings, 1995; Wood, 1995). Therefore, as subsequent learning influences the conceptual structure of prior learning, teachers must explain its connection to prior learning during follow-up classes.

Conclusions and Implications

This study compared the networks of teaching and learning concepts pertaining to the ecosystem-related content in upper secondary schools. This study's conclusions are as follows: First, teachers and students predominantly share the same concept of the entire ecosystem; however, the detailed structures of the key concept networks differ. Regarding the ecosystem's components, teachers primarily explained them in terms of biotic elements, whereas students learned them as a mixture of biotic and abiotic elements. Teachers explained the relationship among

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the concepts of 'Species', 'Community', and 'Population' by connecting all three, whereas students predominantly understood them in terms of the concepts of 'Community' and 'Population'.

Second, the teacher repeatedly utilised the concepts in consecutive classes, rendering it challenging for students to clearly distinguish between the two classes' concepts. The teacher simultaneously employed 32 concepts in the lessons on the 'Ecosystem Components' and 'Interactions between Ecosystem Components' classes, with only two and eight concepts appearing in each class, respectively. Seemingly, students could not clearly distinguish between the concepts covered in these two classes because of similar conceptual statements.

Third, the follow-up learning content influenced the pre-learning. The concepts of 'Carbon dioxide', 'Population', and 'Trophic levels' were presented only in the 'Ecosystem Components' class immediately after the class; however, four weeks later, these concepts connected the two classes. Moreover, the concepts of 'Equilibrium' and 'Food web' appeared four weeks after the class.

In this study, the teachers' teaching concept and the students' learning concept were compared using the concept network to analyse the effective utilization of the concept in the class from the conceptual perspective. In order to complete an effective teaching-learning process, the structural difference between the teachers' teaching concept and the students' learning concept should be reduced. To this end, it is necessary to present concepts in a structured manner by grouping them so that students can easily understand the connection between concepts. rather than repeatedly using concepts. It is thought that presenting concepts clearly distinguished from each In addition, it is necessary to present concepts clearly distinguished from each topic other will help clarify the distinction between follow-up learning and prior learning, that is, the relationship between classes, and will have a positive effect on structuring concepts in students' cognitive structures.

Students learn through the process of reconstructing the learning content presented by the teacher in their own cognitive structures and remembering them. To achieve the educational goal, teachers must consider how students understand and reconstruct concepts, as well as how to organize and conduct classes effectively. Future studies need to analyse how various variables, such as different teaching methods (e.g., inquiry-based classes versus teacher-centred classes) and learner characteristics, affect the learning concept network.

Declaration of Interest

The authors declare no competing interest.

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